OUR ASTRONOMICAL COLUMN.

Comet Perrine.—The following is a continuation of the ephemeris of Comet Perrine for the ensuing week, from Prof. H. Kreutz's computation :—

1898.	R.A.				Dec.			Br.
	h.	m	s.		°	′		
April 22 ...	23	48	19	...	+46	15·0	...	0·64
23 ...		53	37	...	46	50·3		
24 ..	23	58	57	...	47	24·3		
25 ..	0	4	19	...	47	57·1		
26 ...		9	42	...	48	28·7	...	0 58
27 ...		15	6	...	48	59·0		
28 ...	0	20	32	..	+49	28·1		

The Aurora Spectrum.—Prof. E. C. Pickering tells us in a *Circular* (No. 28) of the Harvard College Observatory that the attempts made at photographing the spectrum of the aurora have proved successful, Mr. Edward S. King having obtained two plates, one on April 1, 1897, and the other this year on March 15. On the first of these photographs four bright lines were visible after an exposure of 147 minutes, but uncertainty existed as to the wave-lengths of these lines. In the more recent negative two bright lines were obtained after an exposure of 141 minutes. The brightest of these extends from 3892 to 3925, the wave-length of the second being 4285. Assuming that these two lines were photographed in 1897, the wave-lengths of the four lines then obtained would be 3862, 3922, 4288, 4694.

As regards the first two lines, 3862 and 3922, nothing as yet can be said, as visual observations of the aurora have not extended so far. The line 4288 seems probably to be the same as observed in previous auroræ by Lemström, Wijkander and Oettingen, the wave-lengths given by them being 426, 428 and 424 respectively. The last of the four lines at 469 is a well-observed aurora line, having been seen no less than nine times by observers ; its probable origin is the hot carbon band, which extends from 467-474.

Prof. Pickering mentions that the spectroscope employed to obtain these photographs was not specially designed for the purpose, but a new instrument is in course of construction with which it is hoped better results will be obtained.

The Movement of Solar Faculæ.—By a minute study of the magnificent series of observations on sun-spots, made by Carrington and Spörer, the difference between the times of rotation of the spots in different latitudes has been determined with great accuracy. Thus a strict relation was found to exist between the angular velocity of any spot and its latitude, the former decreasing as the latter increased. Dunér further showed that exactly a similar law existed in the case of the general surface of the sun, but with this exception, that the velocities of each latitude for latitude did not agree. An interesting inquiry was then to investigate the behaviour of the faculæ, which recent photographic methods have shown are so numerous over the solar disc. Faculæ, as many observers of the sun know, are not such stable phenomena as spots ; nevertheless Wilsing, after a laborious investigation, came to the conclusion that they were imbued with a velocity that was constant for all latitudes, and equal to a movement of 14°·27 in 24 hours. Belopolsky, at a later date, adopted a different method of investigation, and was led to draw the conclusion that faculæ obeyed the same law of the variation of the angular velocity of rotation as the spots. More recently Wolfer, after a method somewhat analogous to that employed by Wilsing, came to the same conclusion as that arrived at by Belopolsky.

In consequence of the high importance that would be attached to a definite result of so interesting a problem, Dr. W. Stratonoff has undertaken a very complete investigation of the whole subject, using as his data the fine photographs that have been obtained in the last few years (*Mémoires de l'Académie Impériale des Sciences de St. Pétersbourg. Classe Physico-Mathématique*, vol. v. No. 11). Out of a total number of 400 plates, for the years 1891-1894, he used 234 for this research, as will be seen from the following list, showing by whom they were taken :—

1891 ...	60 ...	Belopolsky.
1892 ...	57 ...	,,
1893 ...	76 ...	,, and Stratonoff.
1894 ...	41 ...	Stratonoff, Orbinsky and Evdokimoff.
Total	234	

We cannot enter at length into the details of the method M. Stratonoff has employed in this long investigation, but must confine ourselves simply to the results obtained. The measurements of the heliographic latitudes and longitudes of each of the 1062 faculæ employed are given in the communication in one table, while a second is confined to the heliographic latitude of each facula with its angular velocity of rotation. The sum total of the research is that Wilsing's result is not corroborated, for it is found that the faculæ in different latitudes do not move with a constant velocity ; in fact, the variation of the angular velocity of rotation must be represented by a more complicated law than that in use for the spots. For latitudes 0°-8° the angular velocity of the faculæ remains nearly constant ; from 9°-16° it decreases rather rapidly to the extent of nearly 0° 4 ; for some range of latitude the velocity becomes again nearly constant, tending to increase rather than decrease. A rapidly slowing down of about 0°·5 takes place between latitudes 25° to 34°, and after that in higher latitudes a very gradual diminution in velocity is noticed more pronounced than was the case in the equatorial zone. Thus it will be seen that velocities of rotation at the highest and lowest latitudes differ by nearly a degree, the characters of this variation being the same for both hemispheres. Spots, it may be added, have the tendency to diminish the velocity of rotation of faculæ. As regards the movements of faculæ, spots, and the solar surface, the faculæ in all latitudes have the greatest velocity of rotation ; then come the spots which move more slowly, and lastly the solar surface, which has the least movement of all. M. Stratonoff suggests that perhaps these facts owe their origin in their difference of heights above the envelope of the sun. The author concludes his interesting paper with a series of instructive curves which convey very clearly to the eye the results of the investigation.

YEAST AND ALCOHOLIC FERMENTATION.

THOUGH the knowledge of the existence of alcoholic fermentation and the preparation of alcoholic liquids dates back to very remote antiquity, it is only within comparatively recent times that an accurate acquaintance with the actual nature of the process has been obtained. By the older writers many processes have been confused together under the name fermentation, though they have nothing in common but the evolution of gas which takes place as they go on. The true alcoholic fermentation, the formation of gas in the intestines of animals, and the effervescence which takes place when an acid is poured upon chalk, have all thus been grouped together as comparable phenomena. Of these different processes, however, that of alcoholic fermentation has been made most widely a subject of study, and from about the end of the seventeenth century definite views as to what it really consists of have been entertained by scientific men.

The correspondence between the alcoholic fermentation of the wort of beer, the must of wine and other saccharine liquids, and the disengagement of a gas under the influence of leaven in the manufacture of bread, had been noticed at a considerably earlier period. Very strange ideas were entertained as to the nature and action of the leaven. It was by some writers held to be of the same nature as that of the hypothetical philosopher's stone, and just as the latter was supposed to be able to transmute all metals by contact with them, so the leaven was considered to be able, in some occult way, to transform the dough into something resembling itself. One fact of importance comes out amidst all the mass of confusion, though its interpretation leaves much to be desired. This is the discovery that a very small quantity of leaven is capable of transforming an almost indefinite amount of the dough. The dough was, however, thought to be converted into leaven, and the capability established was distorted into a mark of identity with the philosopher's stone.

It was known, too, at an early date that besides an evolution of gas, alcoholic fermentation is always accompanied by the formation of a deposit in the fermenting liquid, which takes the form sometimes of a sediment, sometimes of a scum floating on the surface. By many writers considerable importance was attached to this deposit, and to it was attributed some special occult force capable of determining the changes which could be observed. These changes were held by some investigators to be chemical in nature, but still to be altogether different from ordinary chemical reactions. Valentin, who wrote towards the close of the sixteenth century, suggests that the deposited matter communicates to the liquid a kind of internal inflammation, and determines thereby a purification of it, separating its limpid from its turbid constituents. Valentin realised that alcohol makes its appearance in the fermenting liquid, but supposed that it was in some way pre-existent in the extract of the germinated barley grains, and became active and capable of distillation only after being liberated from impurities which accompanied it, and which masked its special properties.

Van Helmont, who wrote in 1648, though confusing fermentation with effervescence, like most writers of the time, yet distinguished that a special gas, which he called the "gas of wine," was produced during the former action, and pointed out that it was different from the spirit of the wine.

Attention was drawn to a distinction between effervescence and fermentation by de la Boë in 1659 and by Lemery in 1675. The first of these writers held the sounder view as to this difference, stating that in effervescence the chief reaction is one of combination, while in fermentation it is a question of decomposition. Lemery held, less accurately, that the chief difference between them was one of relative rapidity, fermentation being a slower and more complicated process. This theory of fermentation is stated by himself in the following words:—

"Pour expliquer cet effet, il faut savoir que le moust contient beaucoup de sel essential; ce sel comme volatil faisant effort dans la fermentation pour se détacher des parties huileuses par lesquelles il etait comme lié, il les pénètre, il les divise et il les écarte jusqu'a ce que par ses pointes subtiles et tranchantes, il les ait raréfiées en esprit; cet effort cause l'ébullition qui arrive au vin, et en même temps sa purification; car il en fait séparer et écarter les parties les plus grossières en forme d'écume, dont une portion s'attache et se pétrifie aux côtés du vase, et l'autre se précipite au fond, c'est ce qu'on appelle le tartre et la lie. L'esprit inflammable du vin n'est donc autre chose qu'une huile exaltée par des sels."

Apparently the first ideas on the subject that may be regarded as at all clear, were advanced by Becher in 1682, and they mark an epoch in the development of our knowledge of it. This author ascertained the fundamental fact that only saccharine liquids are capable of undergoing alcoholic fermentation, and he showed that the alcohol does not exist as such in the original must of wine, but is formed during the operation of fermentation. Becher thought its formation to be due to a kind of combustion, as he ascertained that access of air is needed to set up the phenomenon.

About the same time a theory of the nature of fermentation was advanced, which has much in common with the ideas maintained in later times by Liebig. This was due to Willis and to Stahl, both of whom entertained similar opinions on the subject. It was that the ferment which they recognised as the factor that started the operation is a body possessing a peculiar internal movement or vibration, and that it transmits this vibration to the fermenting material. Of course in the condition of chemical science at the time, there was no satisfactory statement possible as to the nature of the changes caused by such vibration, but Stahl suggested that various decompositions and recombinations resulted therefrom.

The next marked advance in our knowledge must be associated with the name of Lavoisier a century or more later. Up to his time no quantitative researches into the subject had been carried out. The bodies capable of fermentation had been ascertained up to a certain point; besides the alcoholic, the acetic fermentation had been discovered, and a general analogy had been established between fermentation and putrefaction. The products of these fermentations had been ascertained to be carbonic dioxide, alcohol, and acetic acid. Very little acquaintance had been made with the ferment, which was shortly to be recognised as a definite vegetable organism.

While Becher first pointed out the necessity for the presence of sugar in the fermenting liquid, Lavoisier studied quantitatively the relations of the sugar to the derivatives of it formed during the fermentation, and came to the conclusion that the operation consists of a separation of the sugar into two parts, one of which becomes oxygenated to form carbonic dioxide, while the other is converted into alcohol. He says that if it were possible to recombine these two substances, alcohol and carbonic dioxide, sugar would again be formed.

It is apparent that though Lavoisier's methods of analysis were imperfect, and his figures inaccurate in consequence, yet his general conclusions were sound. Towards the year 1815 analyses by Gay-Lussac, Thénard, and de Saussure fixed definitely the composition of sugar and alcohol. These more accurate analyses confirmed Lavoisier's position, but revealed a discrepancy which for a long time remained unexplained. Computation of the composition of sugar based upon the CO_2 and alcohol formed during its fermentation pointed to its having the formula $C_6H_{12}O_6$ (taking the modern values of the atomic weights), the decomposition being capable of expression by the equation $C_6H_{12}O_6 = 2C_2H_6O + 2CO_2$. The analysis made by Gay-Lussac and Thénard of cane-sugar itself demanded the formula $C_{12}H_{22}O_{11}$. These authors were unable to account for the discrepancy which remained unexplained till Dubrunfaut in 1832 observed that before cane-sugar could ferment, it became transformed into another form of sugar which is non-crystallisable. Dumas and Boullay in 1828 tried to reconcile the discrepancy by assuming that the fermentation is accompanied by the absorption of water. We have in the work of these three investigators the substance of what we now know to be true, that the fermentation of cane-sugar involves two processes, the hydrolysis of the cane-sugar with the formation of hexoses, and the decomposition of these with the formation of alcohol and carbonic dioxide.

During the progress of these investigations into the chemistry of fermentation a certain study of the fermenting body was being carried on by various observers. As long ago as 1680 the yeast of beer was examined microscopically by Leuwenhœk, who stated that it was composed of little ovoid or spherical globules, but was not able to determine their nature. Subsequent writers considered them to be of animal origin, but very little was definitely ascertained about them till the fourth decade of the present century, when Cagniard de Latour, repeating Leuwenhœk's experiments, saw that yeast is composed of a mass of organised globules capable of reproduction by budding, and appearing to belong to the vegetable kingdom. He concluded that very probably they disengaged the carbonic dioxide and fermented the liquid by some effect of their vegetation. Before de Latour and writers contemporary with him the yeast was generally considered to be of an animal rather than a vegetable nature, this view being promulgated especially by Fabroni, Desmazières, and Astier, the latter of whom held that it could only live at the expense of the sugar which it decomposed. Since the time of Meyen the true systematic position of yeast has been recognised.

The work of Astier and of C. de Latour laid the foundation for the more complete and satisfactory views of Pasteur, whose researches have thrown so much light upon the whole process of fermentation.

One of the most important discoveries that we owe to Pasteur is that alcoholic fermentation is accompanied by the coincident formation of glycerine and succinic acid, and that, therefore, the equation given above by no means represents all that is taking place in a fermenting liquid. Without committing himself to an equation to represent the whole decomposition, Pasteur determined by quantitative methods that about 4 per cent. of the sugar which disappears in the process of fermentation does not give rise to alcohol, but to glycerine and succinic acid. In addition to ordinary ethylic alcohol, also small quantities of higher alcohols, in varying quantities, are always or generally formed.

Pasteur's theory of fermentation is the natural outcome and the completion of the ideas of Astier and of C. de Latour. In his own words it may be stated: "Mon opinion la plus arrêtée sur la nature de la fermentation alcoolique est celle-ci: L'acte chimique de la fermentation est essentiellement un phénomène corrélatif d'un acte vital, commençant et s'arrêtant avec ce denier. Je pense qu'il n'y a jamais fermentation alcoolique sans qu'il y ait simultanément organisation, développement, multiplication de globules, ou vie continuée, pour suivie, des globules déjà formés."

This hypothesis, originally advanced by C. de Latour, did not, however, obtain acceptance at once. It was opposed strongly by Liebig, who put forward a view which is a modification of that advocated so long before by Willis and by Stahl. According to Liebig, the cause of fermentation is an internal molecular movement or vibration which a body in the course of its decomposition communicates to other matters whose elements are held together with very feeble affinity. Liebig says: "La levure de bière, et en général toutes les matières animales et végétales en putréfaction, reportent sur d'autres corps l'état de décomposition dans lequel elles se trouvent ellesmêmes; le mouvement qui, par la perturbation d'équilibre, s'imprime à leurs propres éléments, se communique également aux éléments des corps qui se trouvent en contact avec elles."

This explanation seemed to apply to all fermentations besides the alcoholic one, and was for that reason favourably received by many; some, indeed, thinking that all fermentations were fundamentally alike, and that the different products were due to the degree of the alteration of the decomposing substance.

This view led to the idea that the action of the yeast was not due to its vital processes, but rather to a decomposition of its proteid constituents regarded simply as nitrogenous substance.

A third hypothesis was advanced by Berzelius, who thought that fermentation is a contact action due to a catalytic force. This idea has met with very little support.

Pasteur's biological explanation of the action of yeast gradually made itself accepted, even to a certain extent modifying Liebig's position. The latter chemist, in his later writings, while adhering to his theory of a molecular vibration, insists that it is not antagonistic to Pasteur's views, but that the movement is set up by the organisms in the course of their vital activity.

The dependence of alcoholic fermentation on the presence of yeast in a living and active condition seemed, so far as the earlier observers went, to be absolute, and the power of the organism to bring it about appeared to indicate a special property of the yeast cell. The question, however, was soon raised whether or no this property was shared by other organisms than this simple one; whether, in fact, it was not rather a manifestation of certain powers of vegetable protoplasm when placed under abnormal conditions. Reasons for holding the latter view were soon forthcoming.

In 1869 MM. Lechartier and Bellamy published an account of some experiments made with ripe fruits, which they kept for several months in the absence of oxygen. They found that under these conditions the fruits gave off continuously a certain quantity of CO_2, and that at the end of the experiment the pulp contained a measurable quantity of alcohol. Microscopic examination of the pulp showed it to be free from any yeast cells. These observations were shortly afterwards confirmed by Pasteur.

In speculating as to the part which these fermentative processes play in the life of the vegetable cell, Pasteur came to the conclusion that the fermentative power was connected with nutrition in the absence of free oxygen, and that the effort to obtain oxygen under these conditions led to the decomposition of the sugar. He strengthened himself in this opinion by experiments on the cultivation of yeast in the absence of free oxygen, carried on side by side with others in which the gas was supplied freely to the organism. In these experiments he found that the relative weights of yeast formed and sugar decomposed were very different under the two conditions. When no oxygen was supplied, fermentation was very slow, and for one part of yeast formed 60 to 80 parts of sugar disappeared. When oxygen was admitted the fermentation was very rapid, but for one part of yeast formed not more than 4 to 10 parts of sugar were decomposed. This difference was not due to any weakening of the energy of the yeast in the second case, for when some of it was removed and made to act on sugar in the absence of oxygen, it behaved just as did that which was used in the first experiment.

In this way Pasteur was led to hold that fermentation is a kind of intra-molecular respiration, a view which, however, was not allowed to pass without challenge.

Schützenberger argues against it with some force, pointing out at the outset that there seems to be a contradiction between the facts and Pasteur's inferences. In the presence of free oxygen we have a very active fermentation set up, while the yeast is said to possess less fermentative power. Schützenberger claims that the fermentative power is not the same thing as the power of growth, nutrition, and multiplication; that it is a distinct quality which exists in the yeast cells so long as they are living, but is not directly related to the respiratory process.

He bases his view on experiments carried out to ascertain how respiration is affected under changed conditions. The results he obtained were briefly the following:—

(1) In a watery liquid without sugar, but containing oxygen in solution, the quantity of oxygen absorbed in unit time by a gramme of yeast is constant, whatever proportion of oxygen is present.

(2) In a saccharine liquid, containing also albuminous matter, and with oxygen in solution, the same result is obtained, except that the quantity absorbed in unit time is greater.

(3) In two digestions, carried on side by side for some time, one being supplied continuously with oxygen and the other deprived of it, the former produced most alcohol.

If the decomposition of the sugar had been the result of the respiratory activity of the yeast cells at the expense of the combined oxygen of the sugar, it would seem that fermentation should either not have taken place at all in the presence of free oxygen, or that it should have been much less than in the other case, whereas the reverse is what is found.

Hence, Schützenberger comes to the conclusion that the sugar is alimentary and not respiratory.

Pasteur's theory has also found a powerful opponent in Naegeli, who held views much like those advanced by Liebig, Willis and Stahl. He thought that the decomposition of the sugar is brought about by vibrations of the plasma molecules, transferred to the fermentable substance, and that it takes place to a small extent only inside the cells, but to a much greater one in the liquid outside them.

A great development of our knowledge of the details of fermentation has taken place during the last twenty years, due in large measure to the labours of Hansen. Prior to 1878 much uncertainty prevailed concerning the true Saccharomycetes. By most laborious and careful cultivation, an acquaintance has been made by him with the life-history and mode of behaviour under various conditions of six definite species of these fungi. Other investigators have described other species, and a copious literature has sprung up on the subject.

Another fact of importance has also been ascertained which explains the discrepancies of analysis observed so long ago by Gay-Lussac, Dumas and others. It was mentioned above, that the composition of the fermented sugar as computed from the measurement of the CO_2 and alcohol it furnished, must be expressed by the formula $C_6H_{12}O_6$, while the analysis of cane-sugar showed it to be $C_{12}H_{22}O_{11}$. Dumas suggested that it took up water during the alcoholic fermentation. It is now known that this hydrolysis takes place before such a fermentation begins, and that it is set up by a special enzyme which can be extracted from yeast. If a watery extract be made of yeast pressed till nearly or quite dry, the cells give up to the solvent a body which has been called *invertin* or *invertase.* When a liquid containing this is added to a solution of cane-sugar, the latter is found to be very rapidly split up according to the equation

$$C_{12}H_{22}O_{11} + H_2O = C_6H_{12}O_6 + C_6H_{12}O_6.$$

Two sugars are formed, one of which rotates a beam of polarised light to the right, the other to the left. These, which were on this account termed *dextrose* and *levulose* respectively, are now known as *glucose* and *fructose.* These two sugars are those which undergo the alcoholic fermentation, while the cane-sugar itself is incapable of so behaving. The extract of the yeast can carry out the hydrolysis without the cells themselves being present.

More recently still, the sugar *maltose,* which is the product formed by the action of diastase on starch, and which is consequently always present in malted grain, has been ascertained to undergo a similar hydrolysis to cane-sugar, but to yield two molecules of glucose in consequence. The enzyme which causes this hydrolysis is also present in the malt. It is called by some writers *glucase,* by others *maltase.*

Fischer states that such an hydrolysis is necessary in the case of all polysaccharides, or sugars with the empirical formula $C_{12}H_{22}O_{11}$. Thus the sugars which are immediately capable of giving rise to alcohol are especially glucose and fructose; those which are commonly found in the liquids which are fermentable being, in addition, cane-sugar and maltose. The latter always undergo conversion or hydrolysis, and form one or both of the former.

The course of action on mixtures of these sugars in the presence of different species of yeast is often very different. Thus Hansen's six true species of Saccharomycetes all hydrolyse both cane-sugar and maltose, besides carrying on alcoholic fermentation of their products. *S. Marxianus* differs in not attacking maltose, while *S. membranæfaciens* ferments none of them, and does not contain invertase. Other organisms have similar idiosyncrasies.

Fischer advances a hypothesis to explain this great variety of action, which throws a great deal of light on the subject. Recognising, as it is now possible to do, that different sugars have different molecular configurations, he suggests that the fermentative principle of the yeast, whatever it may be, must possess a corresponding or complementary configuration, and so be able to come into very close relation to the molecule of the sugar it ferments, much as a key can only unfasten a lock for which it is constructed and to whose parts its own shape corresponds. The configuration of the two fitting as it were into each other, the disruption of the sugar molecule by the action or possibly vibration of the fermentative principle becomes conceivable.

Fischer does not base this hypothesis upon supposition merely, but has tested it by studying the action of some of the soluble enzymes upon the bodies they attack. His results with invertase are very interesting. According to Van 't Hoff's stereochemical theory, there are possibly to be found two methylglucosides, *α* and *β*, which differ only in their configuration. Fischer synthesised both these bodies and heated a quantity of each with 20 times its volume of invertase solution to 30–33° C. At the end of some time about half of the *α* body was hydrolysed, yielding glucose as one of its products. The *β* body underwent no change. Yet the two methyl-glucosides have the same composition, are formed from the same alcohol (methyl alcohol) and from the same sugar (glucose), and differ only in the configuration of a single carbon atom rendered asymmetric by the introduction of the methyl group into the sugar.

The great advances made in the study of fermentations under the action of soluble enyzmes during late years, has drawn the attention of many to the possibility of the secretion of an alcohol-producing enyzme by the yeast cells. It is evident that the introduction of the idea of an enyzme need not involve a new view as to what fermentation itself is. It is only necessary to substitute the secreted enzyme for the protoplasm of the cell, as the active agent in the process.

The idea was advanced some time ago by Berthelot, who compared both lactic and alcoholic fermentations to the conversion of starch into sugar. It has also been suggested by Moritz Traube and by Hoppe-Seyler.

The enyzme has, according to Buchner, actually been prepared from very active yeast by grinding the cells and squeezing the fluid contents from the resulting mass under the very heavy pressure of 500 atmospheres to the square inch.

As a review of Buchner's work appeared in this journal comparatively recently, it is not necessary to recount his experiments in detail.

The discovery, should it be confirmed, deals a very heavy blow to the vibration theories of fermentation due to Liebig and Naegeli. Their views are only tenable on the theory that most, if not all, of the action takes place in the liquid outside the cells. If Buchner is correct, and the work is done by means of an enzyme, it must necessarily be *intra-cellular*, for enzymes, so far as they have at present been investigated, show no tendency to diffuse through such a membrane as the cell wall. It also militates against Pasteur's theory of intramolecular respiration, which demands the idea of the decomposition being brought about by chemical action between the protoplasm and the body from which it, according to the theory, obtains its oxygen.

J. REYNOLDS GREEN.

THE METALS USED BY THE GREAT NATIONS OF ANTIQUITY.[1]

AT the beginning of this century little was known of the great nations of antiquity, except through the classic poets and historians, and the sacred writings of the Hebrew people. Since then our knowledge has been enormously increased by the labours of scholars and explorers; the ruins of ancient cities have been exhumed, and the contemporary literature of Egypt and Assyria, inscribed on papyri or tablets of clay, and painted or carved on the walls of temples, palaces and tombs, has been deciphered. What is in some respects still more important is, that objects found in these ruins have thrown great light upon the daily life of the people, and their ornamental and useful arts. One of the departments of this inquiry concerns the metals used by the different nations, and at the different epochs of their history; and it is to this that my attention will be confined this evening. The difficulty I experience is the vast amount of material; and I cannot attempt anything more than a general view of the subject, and some of the most salient points.

The area over which the inquiry extends is that of the lands bordering on the eastern half of the Mediterranean, and stretching eastwards to the Persian Gulf. The time, so far as Egypt is concerned, includes the whole period from the first Pharaoh, Menes, to the conquest of the country by Alexander the Great; ranging from about B.C. 4400 to B.C. 332. The chronology employed throughout is that of Dr. Wallis Budge, of the British Museum, who has adopted in the main that of Brugsch Bey. This period of 4000 years appears to me reasonable, and errs, if anything, on the side of moderation. Our knowledge of the other nations does not extend to anything like so remote a time.

EGYPT.

If we take as our starting-point Seneferu's triumphal tablet in Wady Maghara, in the Sinaitic peninsula, we see the king flourishing his battle-axe over the head of his enemy. This symbolises the conquest of the copper and turquoise mines of that region, and implies, of course, their previous existence as a source of wealth. In the hieroglyphic inscription above his head there is not only the king's name spelt phonetically, but in the royal titles are seen two ideographs which bear upon our subject. One is the necklace or ornamental collar which is the well-known symbol for gold; and the other an axe, the head of which resembles rather that of a copper than of a stone weapon. These titles have no reference to the metals themselves, but mean "Golden Horus" and "Beneficent Divinity." Before such symbols could be used to express abstract ideas, they must have been well known in their concrete form. The date assigned to Seneferu is B.C. 3750; but the discoveries of the past year have put in our possession the actual metals themselves, of a much greater antiquity. M. de Morgan, late Director General of Antiquities in Egypt, has explored an enormous royal tomb at Nagada, the centre chamber of which contained the mummy of the Pharaoh, with the cartouche of King Menes, the reputed first King of Egypt. If it be really his tomb, the probable date will be B.C. 4400. What is interesting to us is that in two of the chambers, among a multitude of articles made of ivory, quartz, porphyry, wood, alabaster, tortoiseshell, mother-of-pearl, obsidian, earthenware, cornelian, glass and cloth, there were found some small pieces of metal, viz. two or three morsels of gold, and a long bead of that metal of a somewhat crescent form, together with some articles of copper—a kind of button, a bead, and some fine wire. The button was analysed by M. Berthelot, the well-known French chemist and politician, to whom we are indebted for the examination of a very large number of ancient metallic objects; he states that it is nearly pure copper, without arsenic or any other metal in notable proportion.

These are the oldest metallic objects in the world to which we can assign a probable date. But Prof. Flinders Petrie had discovered, three years ago, also at Nagada, a great number of objects of the same character, and among them a few small copper implements. Some filings from a dagger, a celt, and a little harpoon were analysed by me, and found to consist of practically pure copper, without any trace of tin. The remains of these filings are in the little bottles on the table. The age of these tools must be comparable with that of the royal tomb, and may possibly be even older.

Of about the same period, and perhaps even earlier, are a number of tombs at and near Abydos, which have been explored by M. Amélineau, bearing the names of kings unknown to history, accompanied by hieroglyphics of archaic form. In these have been found larger quantities of copper utensils, viz. pots, hatchets, needles, chisels, &c., which M. Berthelot also finds to be nearly pure metal, but some contain a little arsenic. It would appear, therefore, that the Egyptians, at the very beginning of the historic period were acquainted with the use of gold and copper. Let us follow the history of these two metals, beginning with gold, which, as it is generally found native, was probably the first known to man.

According to a letter just received by me from M. Berthelot, all or nearly all the ancient gold that he has examined contains more or less silver. This pale coloured gold is sometimes termed electrum, and was found in great quantity in Asia Minor, where the Pactolus and other streams "rolled down their golden sands." Gold is frequently represented in the Egyptian sculptures and pictures; for instance, in the very interesting scenes of social life at Beni Hassan, *circa* B.C. 2400, illustrations of which I now throw upon the screen, we see the goldsmiths making jewellery, weighing out the metal, melting it in their little furnaces with the aid of blowpipe and pincers, washing it, and working it into the proper forms. In the picture of a bazaar at Thebes we

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[1] A Friday evening discourse delivered at the Royal Institution, on February 11, by Dr. J. H. Gladstone, F.R.S.